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ORIGINAL PAPER

Diversity and regeneration status of woody species in Tara Gedam and Abebaye forests, northwestern Ethiopia

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Abstract: A study was conducted in Tara Gedam and Abebaye forests l, northwestern Ethiopia to investigate the diversity, regeneration status, socio-economic importance and the factors causing destruction of the forests. A total of 30 plots, measuring 20 m ×20 m, were established along line transects laid across the forests. Participatory Rural Appraisal (PRA) method was employed to generate the socio-economic data. Primary data were collected by field observation, semi-structured interview with key informants and discussion with relevant stakeholders. A total of 143 woody species belonging to 114 genera and 57 families were recorded, and of all the species 44 (30.8%) were trees, 57 (39.9%) trees/shrubs, 33 (23.1%) shrubs and 9 (6.3%) lianas. The diversity and evenness of woody species in Tara Gedam forest are 2.98 and 0.65, respectively, and in Abebaye forest they are 1.31 and 0.31, respectively. The total density and basal area of woody species in Tara Gedam forest are 3001 individuals·ha^{-1} and 115.36 m^2·ha^{-1}, respectively, and in Abebaye forest the values are 2850 individuals·ha^{-1} and 49.45 m^2·ha^{-1}, respectively. The results on the importance value index (IVI) and DBH class distributions suggest that the species with low IVI value and poor regeneration status need to be prioritized for conservation. In the socio-economic survey, the responses from the key informants indicated that the forests are the major sources of fuelwood (90%), construction material (80%), timber (75%) and farm implements (55%). The forests are also sources of medicines, animal fodder, bee forage and edible fruits. Tara Gedam monastery, assisted by the local people who have strong religious belief and high respect to the monastery, has played a great role in the maintenance of the sacred forest since a long time. At present, the conservation efforts are made jointly by the monastery and institutions concerned with conservation. The major factors that cause destruction of the forests are livestock grazing, tree cutting for various purposes and farmland expansion. The implications of the results are discussed, and the recommendations are suggested for conservation, management and sustainable utilization of the forest ecosystems.

Keywords: conservation; density; dominance; frequency; IVI; socio-economic importance

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Introduction

Ethiopia is endowed with immense wealth of biological resources due to its diverse topography, soil and climate, which have resulted in ecosystem diversity. Vegetation types in Ethiopia are highly diverse, varying from Afroalpine to desert vegetation. However, the vegetation resources, including forests, are being destroyed at an alarming rate because of a number of factors. The major factors for the destruction of natural forests are agricultural expansion and overexploitation for various purposes such as fuelwood, charcoal, construction material and timber, all spurred by rapid human population growth. Deforestation is one of the biggest challenges for the country. Deforestation and land degradation led to ecological and socio-economic crises in Ethiopia (Gebre Egziabher 1986; Nigatu 1987).

Most of the remaining natural forests in Ethiopia are found in the southern and southwestern parts of the country, and the forests have virtually disappeared from the rest of the country except a few scattered and relatively small areas of forest cover that remained in the northern, central and eastern parts of the country (Gebre Egziabher 1986). Generally, the remaining forests are only small remnant patches mostly confined to inaccessible areas

(mountaintops and steep slopes) and sacred places (churches, monasteries and mosques) (Wassie et al. 2005; Wassie et al. 2009a). With the prevailing alarming rate of deforestation, the remaining natural forests could disappear within a few decades, unless appropriate and immediate measures are taken.

Plants maintain and expand their populations in time and space by the process of regeneration. Regeneration is a complex ecosystem process involving asexual and sexual reproduction, dispersal and establishment in relation to environmental factors (Barnes et al. 1998). It is an ecological process that ensures the development of successive generations of plants. The strategies by which plants regenerate are soil seed banks, seedling banks and vegetative parts (Grime 1979; Garwood 1989; Barnes et al. 1998). Many plant species possess combinations of regenerative strategies. The existence of multiple forms of regeneration has important roles in the evolutionary and ecological potential of the plant. Possession of several strategies increases the range of circumstances in which regeneration can occur, and this, in turn, widens the ecological range of the plant and confers a greater degree of persistence under fluctuating environmental conditions (Grime 1979). Physical factors (e.g. light, temperature, moisture, nutrients and wind), biotic factors (e.g. competition, herbivory and disease) and disturbance regimes strongly influence regeneration processes, and thereby, determine the abundance and status of the plant species.

Understanding the dynamics of soil seed banks and seedling banks of forest vegetation helps to assess the natural regeneration potential of plants (Teketay 1996). Population structure is also an important parameter. The pattern of population structure of woody plants can show the regeneration profile, which is used to determine their regeneration status (Bekele 1994; Teketay 1996). Assessment of soil seed banks, seedling banks and population structure has some practical importance in forest conservation and management. Knowledge of the regeneration status of the plant species is important for developing management strategies and setting priorities.

In Ethiopia, studies that focused on population dynamics and regeneration ecology of forests include Bekele (1994), Teketay (1996), Argaw et al. (1999), Hadera (2000), Bekele (2000), Aleligne (2001), Taye (2001), Wassie (2002), Tesfaye et al. (2002), Shibru (2002), Yeshitela and Bekele (2003), Wassie et al. (2005), Zegeye et al. (2006), Wassie et al. (2009a, b), Wassie et al. (2009) and Tesfaye et al. (2010). The results of these works provide relevant information on the regeneration status of many tree and shrub species, which is of paramount importance to undertake appropriate conservation and management measures.

Tara Gedam and Abebaye forests are one of the remnant forests in northern Ethiopia, and thus, require due attention. There is a need to generate relevant information in order to ensure the conservation, management and sustainable utilization of these forest resources in particular and the biodiversity as a whole. Therefore, the objectives of this study were to: (1) assess the diversity of woody species in the forests; (2) determine the population structure and regeneration status of woody species; (3) investigate the socio-economic importance of the forest resources for the local communities; (4) identify the factors that cause destruction of the forests; (5) assess the forest management systems and the role of the monastery in conserving the forests.

Materials and methods

Study area

The study was carried out in Tara Gedam and Abebaye forests located very close to Addis Zemen town and northeast of Lake Tana, northwestern Ethiopia (Fig. 1). The study area was set in South Gondar Zone within the Amhara National Regional State. Addis Zemen town is located at 12°06'59" N–12°07'25" N and 37°46'14" E–37°47'02" E, on the Addis Ababa-Gondar main road about 82 km north of Bahir Dar and 93 km south of Gondar town. Tara Gedam terrain consists of chains of rugged mountains and hills whereas Abebaye is a gentle hill. The altitude of Tara Gedam ranges from 2 142 to 2 484 m a.s.l. with the highest peak at Wombera Mountain and that of Abebaye from 1 921 to 2 072 m a.s.l.

Most of the areas around Addis Zemen are covered by volcanic rocks mainly basalt. The rocks are light dark, grey, whitish, reddish or brown. The soils are mostly shallow and sandy and characterized by low organic matter. The fertility of the soils in the area deteriorated as a result of erosion and continuous cultivation.

The study area is generally characterized by moderate climate, locally known as ‘woina dega’. The area has a monomodal rainfall distribution and the rainy season is from June to August. The dry season extends from December to March. Climatic data obtained from the National Meteorological Services Agency for the study area showed that the mean annual maximum and minimum temperatures are 27.9°C and 11.1°C, respectively, and the mean annual rainfall is from 900 mm to 1 200 mm.

The area around Addis Zemen was covered by continuous vegetation until recently. However, the vegetation in the area has been destroyed by human activities particularly such as agricultural expansion, excessive exploitation for wood products and human settlement. The depletion of the vegetation is very rapid, and the area is left with remnant small patches of forests, bushlands and shrublands. At present, the land around Addis Zemen is characterized by almost continuous cultivation.

The vegetation of Tara Gedam consists of forests, bushlands, shrublands and mixed/enrichment plantations (plantation stands of exotic species interspersed with stands of natural forest), while the vegetation of Abebaye consists of bushlands and mixed plantations. There is dense natural forest just around the monastery. Tara Gedam and Abebaye forests consist of different trees and shrubs interspersed with climbers and herbs. The area around Addis Zemen is generally poor in wildlife due to pronounced deforestation and high human interference. Tara Gedam and Abebaye forests are habitats for apes, monkeys, bushbuck, klipspringer, antelopes, wild pigs, common fox, leopards, hyenas, serval, mangoose, genet cat, caracal, rock hyrax, rabbit, porcupine and various kinds of birds.

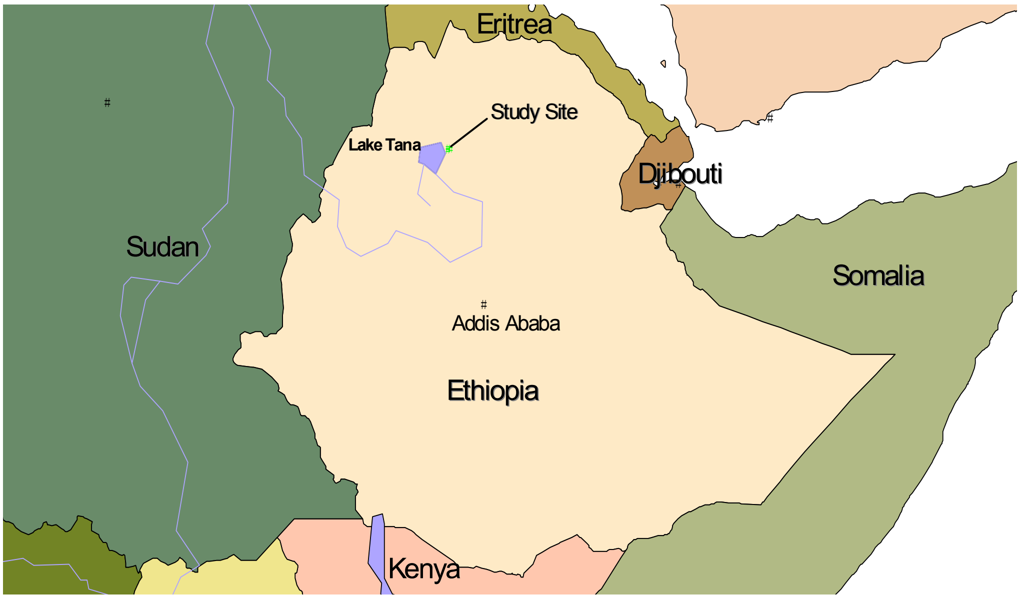

Fig. 1 Map of Ethiopia showing location of the study area

Despite destruction of the vegetation around Addis Zemen, Tara Gedam forest is maintained since a long time owing to the presence of the monastery, which was established during the reign of Atse Gelawdewos in 1600s. On the other hand, Tara Gedam and Abebaye forests were protected as State Forests during the Derge regime in 1979 and 1980, respectively. Currently, Tara Gedam and Abebaye forests have an area of about 975 ha and 133 ha, respectively. The sacred forest shows unique physiognomy that distinguishes and graces the monastery as respected and powerful place.

The inhabitants of the study area are from Amhara ethnic group, and they speak Amharic language. The majority of the people are Orthodox Christians and few are Muslims. The land use systems in the area are farmland, grazing land, forestland, plantation, rural settlement and homegarden, urban settlement and infrastructure development, road, religious site (churches, monasteries and mosques) and water bodies (rivers, streams). Human population growth resulted in shortage of farm and grazing lands. The economy of the local people is predominantly based on subsistence agriculture. The local people are involved in the collection of forest products particularly such as fuelwood, construction material and timber for domestic consumption and income generation. The locale people have limited access to modern health services, and, thus, they partly depend on traditional medicine to fulfill their health care needs. They use medicinal plants, most of which are harvested from the wild, to treat various human and livestock diseases.

Methods

Reconnaissance survey to the study area was made in January 2007 in order to get general information about the physiognomy of the vegetation, socio-economic conditions of the local people, and accessibility to the forests and select sampling sites.

Vegetation sampling

Systematic sampling method was employed for inventory of woody species. Following the line transect method described by Bullock (1996), parallel line transects were laid across the forests in south-north direction determined using Suunto compass. Plots, measuring 20 m × 20 m, were established along the line transects approximately at 100 m intervals. A total of 30 plots were sampled from the forests. In each plot, all woody species were identified by their local and/or scientific names and identities that help for identification were recorded. Trees, shrubs and lianas/woody climbers were counted. Diameters at Breast Height (DBH) ≥ 2 cm of trees and shrubs were measured by using diameter tape following the methods described by Martin (1995) and Cunningham (2001). Individuals of trees and shrubs with DBH < 2 cm were counted by species as seedlings. Woody species that occurred outside the plots were also recorded to produce a more complete list of the woody plants in the study area. The environmental variables, namely altitude and position, of each plot were measured with Magellan GPS 315.

Plant specimens were collected and taken to The National Herbarium (ETH), Addis Ababa University. Identification of the plant specimens was made following the standard methods of identification. Voucher specimens were deposited at The National Herbarium (ETH). Plant nomenclature in this article follows the published volumes of Flora of Ethiopia and Eritrea (Hedberg and Edwards 1989, 1995; Edwards et al. 1995, 2000, 2006; Hedberg et al. 1997, 2003, 2004).

Socio-economic survey

In this survey, Participatory Rural Appraisal (PRA) method was employed to generate the socio-economic data following Martin

(1995) and Cunningham (2001). Primary data were collected by field observation, semi-structured interview with key informants and discussion with relevant stakeholders.

Field observation was made on land use types, extent of soil erosion and forest degradation, soil conservation practices, forest management systems and human impacts on the forest ecosystems.

A semi-structured/open-ended questionnaire was prepared in advance for undertaking the interview and pre-tested. Twenty key informants, suggested to be included in the interview by the forest guards and/or Woreda Agriculture and Rural Development Office, were selected and interviewed using the questionnaire prepared for this purpose. During the interview with key informants, emphasis was given to issues related to the forests in order to get in-depth information about the past and present status, forest management systems, utilization and major threats.

Discussion was made with stakeholders relevant for this study namely, Woreda Administrative Office, Woreda Agriculture and Rural Development Office and Clergymen of Tara Gedam monastery. Relevant points or questions were addressed for respective stakeholders.

Data analysis

The diversity of woody species was determined using the Shannon-Wiener Diversity Index (H') and Evenness or Equitability Index (E) (Krebs 1989; Barnes et al. 1998). The similarity in woody species composition between the forests was computed by using Jaccard's Similarity Coefficient (S_j) (Krebs 1989). The density and percentage frequency of woody species were calculated. The DBH data of trees and shrubs were categorized into nine classes, and presented by using histograms. Basal area of trees and shrubs with DBH ≥ 2 cm was calculated. The Importance Value Index (IVI) (Lamprecht 1989; Kent and Coker 1994) for each woody species was computed using the following formula:

$$\text{Relative density} = \frac{\text{Density of one species}}{\text{Total density}} \times 100 \tag{1}$$

$$\text{Relative frequency} = \frac{\text{Frequency of one species}}{\text{Total frequency}} \times 100 \tag{2}$$

$$\text{Relative dominance/basal area} = \frac{\text{Basal area of one species}}{\text{Total basal area}} \times 100 \tag{3}$$

$$\begin{aligned}\text{IVI} = {} & \text{Relative density} + \text{Relative frequency} + \\ & \text{Relative dominance}\end{aligned} \tag{4}$$

Microsoft Office Excel Software was used for the analysis of the socio-economic data and the results of the analysis were presented using descriptive statistics.

Results and discussion

Floristic composition

A total of 143 woody species representing 114 genera and 57 families were identified from Tara Gedam and Abebaye forests. From the total woody species, 44(30.8%) were trees, 57(39.9%) trees/shrubs, 33(23.1%) shrubs and 9(6.3%) lianas. The trees/shrubs had the largest proportion of the lifeforms. About 6(4.2%) of the woody species were endemic to Ethiopia and these included *Maytenus serrata, Rhus glutinosa, Lippia adoensis, Clematis longicauda, Otostegia tomentosa* and *Millettia ferruginea.* About 26 (18.2%) of the woody species were cultivated trees and shrubs. The trees and shrubs of Tara Gedam forest comprise mostly species characteristic of forests, whereas that of Abebaye forest comprise mostly species characteristic of woodlands. This is mainly due to altitudinal difference between the two sites though they are close to each other. Some of the woody species in Tara Gedam forest like *Prunus africana, Albizia gummifera, Scolopia theifolia, Lepidotrichilia volkensii* and *Ritchiea albersii* were also found in the forests of the western, southwestern, southern and eastern parts of the country (Friis 1992).

Similarity in woody species composition

From the total species identified, 56 species (39.1%) were found in both Tara Gedam and Abebaye forests, 55 species (38.5%) in Tara Gedam forest only and 32 (22.4%) species in Abebaye forest only (Appendix 1). The similarity in species composition between Tara Gedam and Abebaye forests was 0.36. The similarity coefficient was below 0.5 (maximum is 1.0), indicating that there is low similarity among the forests and each forest has its own characteristic species. This is mainly attributed to altitudinal difference between the two sites although they are close to each other. Thus, both Tara Gedam and Abebaye forests are important in terms of floristic diversity and sensitive from a conservation point of view.

Diversity of woody species

The diversity and evenness of woody species in Tara Gedam forest were 2.98 and 0.65, respectively, and in Abebaye forest 1.31 and 0.31, respectively (Table 1). The results indicated that Tara Gedam forest had higher diversity and evenness than Abebaye forest, and this may be attributed to altitudinal difference, habitat diversity and low human disturbance as it is respected monastery. The evenness value 0.65 (maximum is 1.00) for Tara Gedam forest showed that there is more or less balanced distribution of individuals of different species. On the other hand, the low evenness for Abebaye forest indicated that there is unbalanced representation of individuals of different species because of high human disturbance as well as site and species characteristics. The reason for low evenness can be attributed to excessive

disturbance, variable conditions for regeneration and exploitation of some species (Wassie et al. 2005). The diversity and evenness indices imply the need to conserve the forests from both floristic diversity and human disturbance perspectives.

Table 1. Comparison of richness, diversity (*H′*) and evenness (*E*) of woody species among Tara Gedam and Abebaye forests

Forest	Richness		Diversity	Evenness
	Families	Species	*H′*	*E*
Tara Gedam	54	113	2.98	0.65
Abebaye	45	89	1.31	0.31

Density and frequency of woody species

The total density of woody species in Tara Gedam and Abebaye forests were 3 001 and 2 850 individuals·ha^{-1}, respectively (Tables 2 and 3). Tara Gedam forest had higher density than Abebaye forest. This is due to low human disturbance in Tara Gedam forest as it is respected monastery, whereas, in Abebaye forest, there is relatively high human disturbance.

Table 2. Density, relative density, frequency, relative frequency, basal area, relative basal area and IVI of woody species in Tara Gedam forest

Species	Density	Relative density (%)	Frequency (%)	Relative frequency (%)	Basal area (m^2·ha^{-1})	Relative basal area (%)	IVI
Acacia abyssinica	29.76	0.99	19.05	1.07	2.79	2.41	30.31
Acacia lahai	21.43	0.71	9.52	0.53	0.53	0.46	13.77
Acacia pilispina	60.71	2.02	23.81	1.34	0.19	0.16	32.52
Acanthus polystachius	55.95	1.86	28.57	1.60	0.04	0.03	38.11
Acokanthera schimperi	33.33	1.11	9.52	0.53	-	-	-
Albizia gummifera	252.38	8.41	80.95	4.55	10.58	9.17	130.66
Apodytes dimidiata	20.24	0.67	14.29	0.80	3.39	2.94	25.10
Barleria ventricosa	3.57	0.12	4.76	0.27	-	-	-
Bersama abyssinica	33.33	1.11	23.81	1.34	0.44	0.38	32.08
Bridelia micrantha	5.95	0.20	9.52	0.53	1.39	1.21	14.86
Brucea antidysenterica	19.05	0.63	14.29	0.80	0.01	0.01	18.75
Buddleja polystachya	15.48	0.52	14.29	0.80	0.01	0.01	18.63
Calotropis procera	4.76	0.16	4.76	0.27	-	-	-
Calpurnia aurea	245.24	8.17	61.90	3.48	1.08	0.94	88.57
Capparis tomentosa	30.95	1.03	33.33	1.87	-	-	-
Carissa spinarum	96.43	3.21	71.43	4.01	0.58	0.50	94.73
Cissus quadrangularis	2.38	0.08	4.76	0.27	-	-	-
Clausena anisata	23.81	0.79	23.81	1.34	0.02	0.02	30.98
Clematis longicauda	4.76	0.16	9.52	0.53	-	-	-
Clerodendrum myricoides	2.38	0.08	4.76	0.27	0.01	0.01	6.12
Clutia abyssinica	2.38	0.08	4.76	0.27	-	-	-
Clutia lanceolata	59.52	1.98	28.57	1.60	0.03	0.03	38.22
Combretum molle	11.90	0.40	19.05	1.07	0.79	0.68	25.99
Cordia africana	13.10	0.44	19.05	1.07	0.40	0.35	25.31
Croton macrostachyus	61.90	2.06	47.62	2.67	0.47	0.41	63.23
Dodonaea angustifolia	154.76	5.16	33.33	1.87	0.25	0.22	47.83
Dombeya torrida	9.52	0.32	4.76	0.27	0.39	0.34	7.08
Dovyalis abyssinica	8.33	0.28	14.29	0.80	0.37	0.32	19.06
Ehretia cymosa	3.57	0.12	4.76	0.27	-	-	-
Ekebergia capensis	107.14	3.57	38.10	2.14	9.36	8.11	69.28
Embelia schimperi	2.38	0.08	4.76	0.27	-	-	-
Euclea racemosa subsp. *schimperi*	7.14	0.24	9.52	0.53	0.09	0.08	12.47
Euphorbia abyssinica	20.24	0.67	14.29	0.80	0.12	0.11	18.99
Ficus sur	7.14	0.24	9.52	0.53	1.20	1.04	14.54
Ficus sycomorus	3.57	0.12	4.76	0.27	0.03	0.02	6.20
Ficus thonningii	2.38	0.08	4.76	0.27	0.06	0.05	6.22
Ficus vasta	5.95	0.20	9.52	0.53	7.71	6.68	26.65
Gnidia glauca	11.90	0.40	14.29	0.80	-	-	-
Grewia ferruginea	41.67	1.39	42.86	2.41	0.23	0.20	56.07
Gymnema sylvestre	2.38	0.08	4.76	0.27	-	-	-
Hymenodictyon floribundum	2.38	0.08	4.76	0.27	0.26	0.23	6.60
Hypericum quartinianum	29.76	0.99	23.81	1.34	-	-	-
Jasminum grandiflorum subsp. *floribundum*	38.10	1.27	38.10	2.14	-	-	-
Juniperus procera	21.43	0.71	14.29	0.80	0.11	0.10	19.01
Justicia schimperiana	83.33	2.78	9.52	0.53	-	-	-
Lannea schimperi	2.38	0.08	4.76	0.27	0.26	0.23	6.60
Lepidotrichilia volkensii	4.76	0.16	4.76	0.27	-	-	-
Lippia adoensis	22.62	0.75	19.05	1.07	-	-	-

Continued Table 2

Species	Density	Relative density (%)	Frequency (%)	Relative frequency (%)	Basal area ($m^2 \cdot ha^{-1}$)	Relative basal area (%)	IVI
Maesa lanceolata	4.76	0.16	4.76	0.27	0.13	0.11	6.42
Maytenus arbutifolia	45.24	1.51	23.81	1.34	0.07	0.06	31.78
Maytenus obscura	4.76	0.16	9.52	0.53	0.58	0.50	13.30
Maytenus serrata	60.71	2.02	38.10	2.14	0.01	0.01	50.28
Millettia ferruginea	7.14	0.24	9.52	0.53	0.29	0.26	12.85
Mimusops kummel	17.86	0.60	9.52	0.53	0.52	0.45	13.63
Myrsine africana	9.52	0.32	4.76	0.27	0.03	0.03	6.41
Nuxia congesta	41.67	1.39	33.33	1.87	1.60	1.39	46.58
Ocimum urticifolium	53.57	1.79	19.05	1.07	-	-	-
Olea europaea subsp. c*uspidata*	203.57	6.78	61.90	3.48	47.06	40.79	173.02
Opuntia ficus-indica	4.76	0.16	4.76	0.27	-	-	-
Osyris quadripartita	48.81	1.63	42.86	2.41	0.07	0.06	56.02
Otostegia integrifolia	22.62	0.75	14.29	0.80	-	-	-
Pavetta abyssinica	8.33	0.28	9.52	0.53	0.03	0.02	12.38
Pavetta oliveriana	3.57	0.12	4.76	0.27	-	-	-
Pavonia urens	4.76	0.16	4.76	0.27	-	-	-
Phoenix reclinata	1.19	0.04	4.76	0.27	-	-	-
Phytolacca dodecandra	5.95	0.20	4.76	0.27	-	-	-
Premna schimperi	39.29	1.31	33.33	1.87	0.26	0.22	43.99
Protea gaguedi	3.57	0.12	4.76	0.27	0.01	0.01	6.17
Prunus africana	5.95	0.20	9.52	0.53	1.42	1.23	14.91
Pterolobium stellatum	67.86	2.26	47.62	2.67	-	-	-
Rhamnus staddo	39.29	1.31	33.33	1.87	0.09	0.08	43.68
Rhus glutinosa	83.33	2.78	47.62	2.67	1.37	1.19	65.63
Rhus vulgaris	29.76	0.99	14.29	0.80	0.02	0.02	19.12
Ritchiea albersii	4.76	0.16	9.52	0.53	0.32	0.28	12.82
Rosa abyssinica	15.48	0.52	23.81	1.34	0.02	0.02	30.69
Rubus steudneri	2.38	0.08	4.76	0.27	-	-	-
Rumex nervosus	42.86	1.43	23.81	1.34	-	-	-
Sapium ellipticum	3.57	0.12	4.76	0.27	0.81	0.70	7.66
Schefflera abyssinica	21.43	0.71	19.05	1.07	11.83	10.26	46.92
Schrebera alata	89.29	2.98	57.14	3.21	2.85	2.47	80.65
Scolopia theifolia	61.90	2.06	33.33	1.87	1.62	1.41	47.29
Senna didymobotrya	17.86	0.60	4.76	0.27	0.03	0.03	6.68
Solanum anguivi	4.76	0.16	9.52	0.53	-	-	-
Solanum giganteum	23.81	0.79	4.76	0.27	0.12	0.10	7.04
Solanum incanum	3.57	0.12	4.76	0.27	-	-	-
Solanum marginatum	7.14	0.24	4.76	0.27	-	-	-
Steganotaenia araliacea	8.33	0.28	14.29	0.80	0.07	0.06	18.49
Stereospermum kunthianum	14.29	0.48	23.81	1.34	0.14	0.12	30.89
Syzygium guineense	2.38	0.08	4.76	0.27	0.15	0.13	6.38
Teclea nobilis	22.62	0.75	23.81	1.34	0.30	0.26	31.47
Urera hypselodendron	2.38	0.08	4.76	0.27	-	-	-
Vernonia amygdalina	19.05	0.63	14.29	0.80	0.01	0.01	18.75
Vernonia brachycalyx	2.38	0.08	4.76	0.27	-	-	-
Vernonia congolensis	3.57	0.12	4.76	0.27	-	-	-
Vernonia myriantha	98.81	3.29	57.14	3.21	0.29	0.26	76.19
Ximenia americana	7.14	0.24	9.52	0.53	0.01	0.01	12.32
Total	3,001.19	100.00	1,780.95	100.00	115.36	100.00	2,094.95

Table 3. Density, relative density, frequency, relative frequency, basal area, relative basal area and IVI of woody species in Abebaye forest

Species	Density	Relative density (%)	Frequeny (%)	Relative fre-quency (%)	Basal area ($m^2 \cdot ha^{-1}$)	Relative basal area (%)	IVI
Acacia lahai	486.11	17.06	77.78	3.63	8.01	16.20	129.67
Acacia pilispina	336.11	11.79	100.00	4.66	4.31	8.71	138.48
Acacia seyal	13.89	0.49	11.11	0.52	-	-	-
Acanthus polystachius	261.11	9.16	88.89	4.15	-	-	-
Acokanthera schimperi	13.89	0.49	22.22	1.04	-	-	-
Asparagus africanus	5.56	0.19	11.11	0.52	-	-	-
Bersama abyssinica	50.00	1.75	22.22	1.04	0.07	0.14	27.22

Continued Table 3

Species	Density	Relative density (%)	Frequeny (%)	Relative fre-quency (%)	Basal area ($m^2 \cdot ha^{-1}$)	Relative basal area (%)	IVI
Bridelia micrantha	5.56	0.19	11.11	0.52	0.02	0.03	12.87
Brucea antidysenterica	5.56	0.19	11.11	0.52	-	-	-
Calpurnia aurea	50.00	1.75	44.44	2.07	0.81	1.64	54.73
Capparis tomentosa	102.78	3.61	100.00	4.66	-	-	-
Carissa spinarum	94.44	3.31	77.78	3.63	0.41	0.82	92.95
Celtis africana	13.89	0.49	22.22	1.04	0.03	0.07	25.84
Cissus quadrangularis	41.67	1.46	33.33	1.55	-	-	-
Clematis hirsuta	16.67	0.58	33.33	1.55	-	-	-
Clerodendrum myricoides	2.78	0.10	11.11	0.52	-	-	-
Combretum molle	19.44	0.68	22.22	1.04	0.79	1.60	28.33
Commiphora habessinica	8.33	0.29	11.11	0.52	-	-	-
Cordia africana	16.67	0.58	44.44	2.07	0.88	1.77	53.75
Croton macrostachyus	63.89	2.24	100.00	4.66	4.40	8.90	129.21
Dichrostachys cinerea	11.11	0.39	22.22	1.04	-	-	-
Dodonaea angustifolia	58.33	2.05	44.44	2.07	-	-	-
Dombeya torrida	5.56	0.19	11.11	0.52	0.01	0.01	12.84
Dovyalis abyssinica	13.89	0.49	22.22	1.04	-	-	-
Entada abyssinica	22.22	0.78	11.11	0.52	0.52	1.04	14.97
Erythrina abyssinica	8.33	0.29	22.22	1.04	0.01	0.03	25.59
Euclea racemosa subsp. *schimperi*	27.78	0.97	44.44	2.07	0.04	0.09	51.62
Euphorbia tirucalli	8.33	0.29	11.11	0.52	0.05	0.10	13.06
Ficus sur	5.56	0.19	22.22	1.04	2.46	4.98	32.90
Ficus sycomorus	2.78	0.10	11.11	0.52	2.18	4.41	19.32
Ficus vasta	5.56	0.19	22.22	1.04	16.77	33.91	76.13
Flueggea virosa	5.56	0.19	11.11	0.52	-	-	-
Gardenia ternifolia	22.22	0.78	44.44	2.07	-	-	-
Grewia ferruginea	27.78	0.97	33.33	1.55	0.04	0.09	38.99
Hibiscus macranthus	19.44	0.68	22.22	1.04	-	-	-
Hypericum quartinianum	8.33	0.29	22.22	1.04	-	-	-
Indigofera tinctoria	5.56	0.19	11.11	0.52	-	-	-
Jasminum grandiflorum subsp. *floribundum*	33.33	1.17	77.78	3.63	-	-	-
Lannea schimperi	2.78	0.10	11.11	0.52	1.07	2.16	15.96
Leonotis ocymifolia	16.67	0.58	22.22	1.04	-	-	-
Maesa lanceolata	5.56	0.19	11.11	0.52	0.02	0.04	12.89
Maytenus serrata	252.78	8.87	88.89	4.15	-	-	-
Nuxia congesta	13.89	0.49	22.22	1.04	0.17	0.34	26.25
Ocimum urticifolium	77.78	2.73	55.56	2.59	-	-	-
Opuntia ficus-indica	11.11	0.39	11.11	0.52	-	-	-
Osyris quadripartita	22.22	0.78	44.44	2.07	-	-	-
Otostegia tomentosa	22.22	0.78	33.33	1.55	-	-	-
Pavetta abyssinica	11.11	0.39	11.11	0.52	-	-	-
Phytolacca dodecandra	5.56	0.19	11.11	0.52	-	-	-
Pluchea dioscoridis	8.33	0.29	11.11	0.52	-	-	-
Premna schimperi	55.56	1.95	55.56	2.59	0.21	0.43	65.74
Pterolobium stellatum	127.78	4.48	77.78	3.63	-	-	-
Rhoicissus tridentata	13.89	0.49	22.22	1.04	-	-	-
Rhus glutinosa	16.67	0.58	33.33	1.55	0.20	0.41	39.09
Rhus vulgaris	41.67	1.46	33.33	1.55	0.05	0.10	39.49
Ricinus communis	8.33	0.29	11.11	0.52	-	-	-
Sapium ellipticum	8.33	0.29	33.33	1.55	3.34	6.75	48.26
Schrebera alata	22.22	0.78	33.33	1.55	0.08	0.15	38.89
Senna didymobotrya	47.22	1.66	22.22	1.04	-	-	-
Senna singueana	8.33	0.29	22.22	1.04	-	-	-
Sesbania sesban	36.11	1.27	22.22	1.04	-	-	-
Solanum anguivi	2.78	0.10	11.11	0.52	-	-	-
Steganotaenia araliacea	25.00	0.88	33.33	1.55	0.02	0.03	38.81
Stereospermum kunthianum	2.78	0.10	11.11	0.52	-	-	-
Syzygium guineense	8.33	0.29	11.11	0.52	2.40	4.85	20.17
Triumfetta pilosa	8.33	0.29	11.11	0.52	-	-	-
Vernonia myriantha	55.56	1.95	33.33	1.55	0.10	0.19	40.12
Ximenia americana	11.11	0.39	11.11	0.52	-	-	-
Total	2,850.0	100.00	2,144.44	100.00	49.45	100.00	1,364.16

In Tara Gedam forest, the species with the highest density was *A. gummifera* (252.38 individuals·ha^{-1}), followed by *Calpurnia aurea* (245.24 individuals·ha^{-1}), *Olea europaea* subsp. *cuspidata* (203.57 individuals·ha^{-1}), *Dodonaea angustifolia* (154.76 individuals·ha^{-1}), *Ekebergia capensis* (107.14 individuals·ha^{-1}), *Vernonia myriantha* (98.81 individuals·ha^{-1}), *Carissa spinarum* (96.43 individuals·ha^{-1}), *Schrebera alata* (89.29 individuals·ha^{-1}), *Rhus glutinosa* (83.33 individuals·ha^{-1}) and *Justicia schimperiana* (83.33 individuals·ha^{-1}). The species with the highest frequency was *A. gummifera* (80.95%), followed by *C. spinarum* (71.43%), *C. aurea* (61.90%), *O. europaea* subsp. *cuspidata* (61.90%), *V. myriantha* (57.14%), *S. alata* (57.14%), *R. glutinosa* (47.62%), *Pterolobium stellatum* (47.62%) and *Croton macrostachyus* (47.62%).

In Abebaye forest, the species with the highest density was *Acacia lahai* (486.11 individuals·ha^{-1}), followed by *A. pilispina* (336.11 individuals·ha^{-1}), *Acanthus polystachius* (261.11 individuals·ha^{-1}), *Maytenus serrata* (252.78 individuals·ha^{-1}), *P. stellatum* (127.78 individuals·ha^{-1}), *Capparis tomentosa* (102.78 individuals·ha^{-1}) and *C. spinarum* (94.44 individuals·ha^{-1}). The species with the highest frequency were *A. pilispina*, *C. tomentosa* and *C. macrostachyus* (100% each), followed by *A. polystachius* (88.89%), *M. serrata* (88.89%), *A. lahai* (77.78%), *P. stellatum* (77.78%), *C. spinarum* (77.78%) and *Jasminum grandiflorum* subsp. *floribundum* (77.78%).

The high frequency indicates regular horizontal distribution of the species in the forests. The variation in density and frequency between species may be attributed to habitat differences, habitat preferences among the species, species characteristics for adaptation, degree of exploitation and conditions for regeneration.

Basal area and IVI of woody species

The total basal area of woody species in Tara Gedam and Abebaye forests were 115.36 and 49.45 m^2·ha^{-1}, respectively (Tables 2 and 3). The reason for such variation is that Tara Gedam forest has old-aged and big trees, whereas, Abebaye forest is dominated by shrubs and small trees.

In Tara Gedam forest, the species with the highest basal area was *O. europaea* subsp. *cuspidata* (47.06 m^2·ha^{-1}), followed by *Schefflera abyssinica* (11.83 m^2·ha^{-1}), *A. gummifera* (10.58 m^2·ha^{-1}), *E. capensis* (9.36 m^2·ha^{-1}), *Ficus vasta* (7.71 m^2·ha^{-1}), *Apodytes dimidiata* (3.39 m^2·ha^{-1}), *S. alata* (2.85 m^2·ha^{-1}) and *Acacia abyssinica* (2.79 m^2·ha^{-1}). Some species like *S. abyssinica*, *A. dimidiata* and *F. vasta* had high basal area because of their large size though they had low density and frequency. On the other hand, some species like *C. aurea* and *D. angustifolia* had high density and frequency, but their basal area was low due to their smaller diameter or size.

In Abebaye forest, the species with the highest basal area was *F. vasta* (16.77 m^2·ha^{-1}), followed by *A. lahai* (8.01 m^2·ha^{-1}), *C. macrostachyus* (4.40 m^2·ha^{-1}), *A. pilispina* (4.31 m^2·ha^{-1}), *Sapium ellipticum* (3.34 m^2·ha^{-1}), *F. sur* (2.46 m^2·ha^{-1}), *Syzygium guineense* (2.40 m^2·ha^{-1}) and *F. sycomorus* (2.18 m^2·ha^{-1}). Some species like *F. vasta*, *F. sur*, *F. sycomorus* and *S. guineense* had high basal area because of their large size though they had low density and frequency.

In Tara Gedam forest, the species with the highest IVI value was *O. europaea* subsp. *cuspidata* (173.02), followed by *A. gummifera* (130.66), *C. spinarum* (94.73), *C. aurea* (88.57), *S. alata* (80.65), *V. myriantha* (76.19), *E. capensis* (69.28), *R. glutinosa* (65.63) and *C. macrostachyus* (63.23). The high IVI value of *C. aurea* and *V. myriantha* was because of their high relative density and relative frequency, though they had low relative dominance/basal area.

In Abebaye forest, the species with the highest IVI value was *A. pilispina* (138.48), followed by *A. lahai* (129.67), *C. macrostachyus* (129.21), *C. spinarum* (92.95), *F. vasta* (76.13), *Premna schimperi* (65.74), *C. aurea* (54.73), *Cordia africana* (53.75) and *Euclea racemosa* subsp. *schimperi* (51.62). The high IVI value of *C. spinarum* and *P. schimperi* was because of their high relative density and relative frequency though they had low relative basal area. On the other hand, the high IVI value of *F. vasta* was because of its high relative basal area though it had low relative density and relative frequency.

IVI value is an important parameter that reveals the ecological significance of species in a given ecosystem (Lamprecht 1989). Species with high IVI values are considered more important than those with low IVI value. The IVI values can also be used to prioritize species for conservation, and species with high IVI value need less conservation efforts, whereas, those having low IVI value need high conservation effort (Shibru 2002). The results suggest that the species having low IVI value should be prioritized for conservation.

Regeneration status of woody species

The DBH class distributions of the species exhibited different patterns (Fig. 2 and 3), and showed that there are species with high number of individuals in the lower classes, some species in the middle classes and others in the higher classes. Sign of selective removal was observed for *O. europaea* subsp. *cuspidata* and *E. capensis*. This is because the former has been cut for construction material, charcoal production and farm implements, and the latter for fuelwood and timber.

The patterns of DBH class distributions indicated the general trends of population dynamics and recruitment processes of the species. From the DBH class distributions of the species, two types of regeneration status were determined, i.e. good and poor regeneration. Some species possessed high number of individuals in the lower DBH classes, particularly in the first class, which suggests that they have good regeneration potential. Other species possessed either no or few number of individuals in the lower DBH classes, particularly in the first class, which indicates that the species are in poor regeneration status. Species which showed good regeneration status included *A. gummifera, C. aurea*, *E. capensis* and *S. alata*. Species which showed poor regeneration status include *O. europaea* subsp. *cuspidata, A. abyssinica, Scolopia theifolia* and *Entada abyssinica*. The major reasons for hampered or poor regeneration are unfavourable

environmental conditions like rocky land and poorly developed soil, and human disturbance particularly livestock grazing. On the other hand, prevention of livestock grazing and overexploitation can improve the regeneration status of woody species.

The DBH class distribution of all woody species in Tara Gedam forest showed a reverse "J" distribution. There are high number of individuals in the first and second classes with gradual decrease towards the middle and higher classes. Similarly, the DBH class distribution of all woody species in Abebaye forest showed a reverse "J" distribution with slight deviation in the first class. There are small number of individuals in the first class, high number of individuals in the second class, and then decrease to the middle classes. Except *C. macrostachyus*, the woody species in Abebaye forest had no individuals in the higher classes since they were shrubs or small trees. Reverse "J" distribution is considered as an indication of stable population structure or good regeneration status (Silvertown 1982; Silvertown and Doust 1993; Bekele 1994; Teketay 1997; Aleligne 2001; Wassie et al. 2005; Tesfaye et al. 2002; Shibru, 2002; Zegeye et al. 2006; Tesfaye et al. 2010). However, it is important to note that some of the species are in poor regeneration status, and, thus, should be prioritized for conservation.

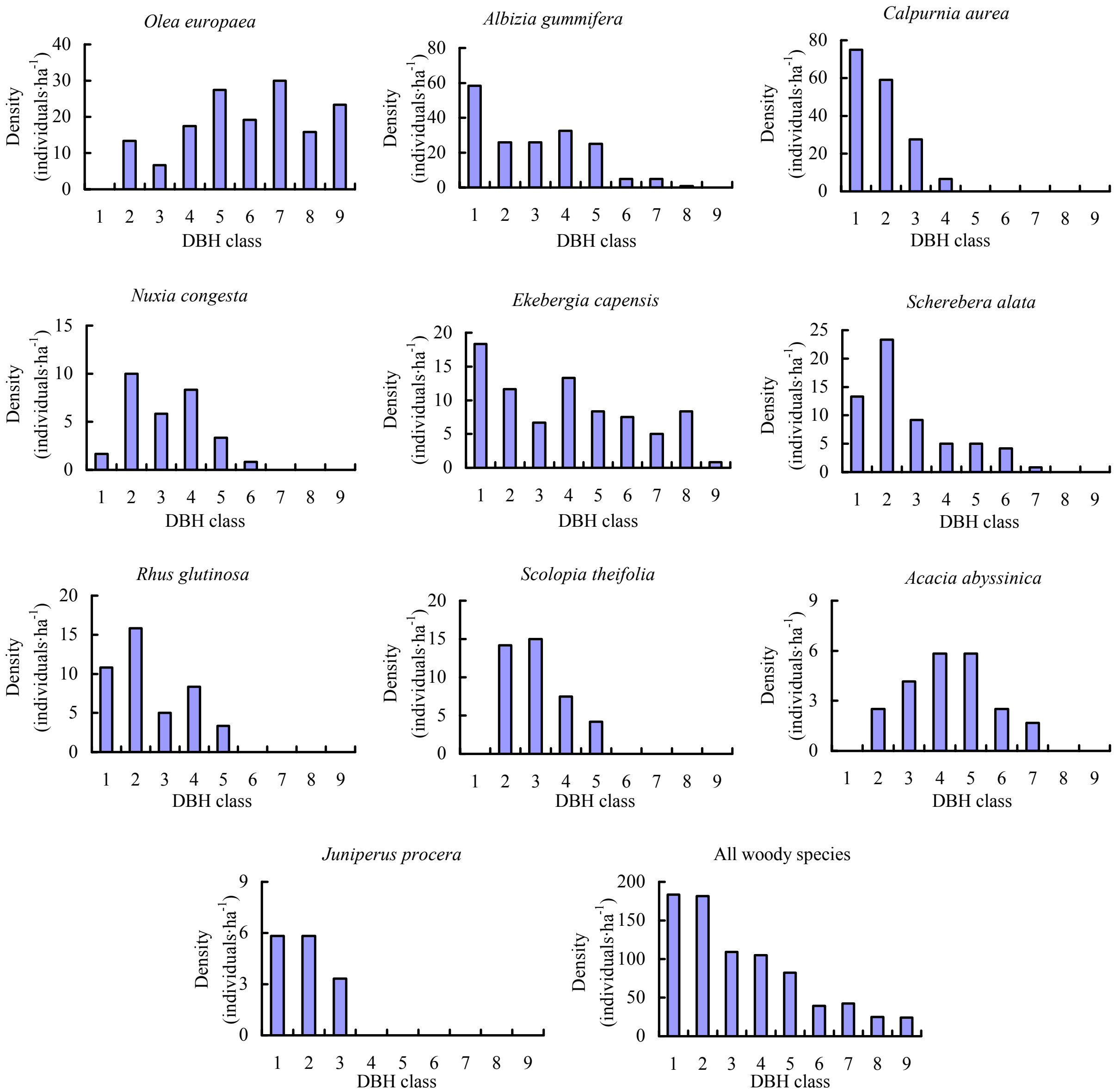

Fig. 2 DBH class distributions of some selected trees and shrubs and all woody species in Tara Gedam forests. (DBH classes: 1: < 2 cm; 2: 2–10 cm; 3: 10–20 cm; 4: 20–30 cm; 5: 30–40 cm; 6: 40–50 cm; 7: 50–60 cm; 8: 60–70 cm; 9: > 70 cm).

Values of the forest resources

The responses from the key informants indicated that Tara Gedam and Abebaye forests are the major sources of fuelwood (90%), construction material (80%), timber (75%) and farm implements (55%). They are also the sources of medicines, animal

fodder, bee forage and edible fruits. They are the only sources of forest products for the local people since there are no alternative forests in the vicinity. They also provide employment opportunities for forest guards. The forests are potential sites for scientific research, education and tourism industry.

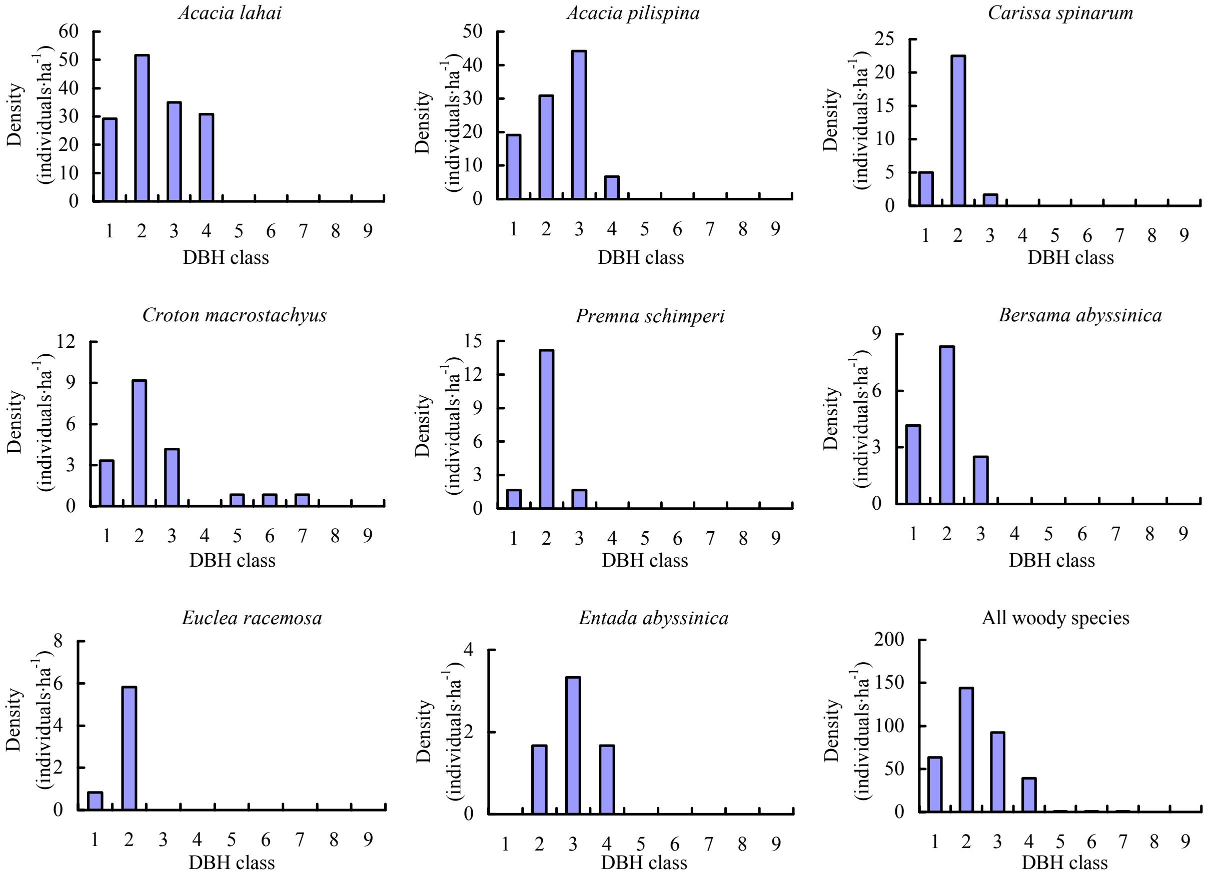

Fig. 3 DBH class distributions of some selected trees and shrubs and all woody species in Abebaye forests. (DBH classes: 1: < 2 cm; 2: 2–10 cm; 3: 10–20 cm; 4: 20–30 cm; 5: 30–40 cm; 6: 40–50 cm; 7: 50–60 cm; 8: 60–70 cm; 9: > 70 cm).

Indigenous resource management systems

The local people have environmentally friendly resource management systems and practices. Terracing and traditional agroforestry are widely practiced in the area (personal observation). The major reason for constructing terraces is to control soil erosion and improve soil fertility. Thereby, crop production increases. In addition, the local people construct terraces on farm boundary to serve as demarcation lines between adjacent farmlands of different farmers. The local people retain and/or plant indigenous trees (e.g. *Cordia africana*, *A. abyssinica*, *Combretum molle, C. macrostachyus*, *S. ellipticum*, *Ficus* spp.) in the farmlands. They also plant exotic species (e.g. *Eucalyptus camaldulensis*, *Jacaranda mimosifolia*, *Melia azedarach*, *Schinus molle*, *Spathodea campanulata* subsp. *nilotica*) in the homesteads, farm woodlots, road sides and compounds of institutions. Besides control of soil erosion, trees retained and/or planted in the agroforestry systems provide various products such as fuelwood, construction material, farm implements, animal fodder and bee forage. They also serve as shade and live fences. Thus, the agroforestry systems reduce the pressure on the natural forests. The indigenous resource management systems and practices are of great importance and deserve special attention since they have the potential to promote the conservation of biodiversity. The indigenous/traditional resource conservation and management systems and practices of rural communities in Ethiopia promoted the conservation of genetic resources for centuries (Teketay 1999).

Forest protection and management

The discussion with the relevant stakeholders showed that the responsibility for the conservation, management and sustainable utilization of the forests mainly rests on Tara Gedam monastery and Woreda Agriculture and Rural Development Office. Accordingly, there is regular forest protection by guards employed on permanent basis. However, there is no proper legal framework for forest protection. Moreover, fire control gaps or firebreaks, each having a width of about 20 m, have been established in Abebaye forest in order to reduce the impact of fire incidence. On the other hand, it is important to note that strict protection

and exclusion of the local people from utilization of the forest resources is against the modern conservation approach, which states that the conservation is the maintenance and sustainable utilization of natural resources. Thus, sustainable utilization like controlled grazing and cutting of trees for construction poles and farm implements, collection of dried logs, grasses (through cut-and-carry system), medicinal herbs or parts of trees/shrubs for medicines and climbers for making beehives, beekeeping in the forests, etc. should be allowed to develop sense of ownership in the local people and ensure the long-term maintenance of the forests.

Human impacts on the forest ecosystems

The survey showed that the increasing demand for agricultural lands and wood products, spurred by human population growth, have led to the destruction of Tara Gedam and Abebaye forests. At present, the forest resources are under great human pressure and will diminish in the near future unless appropriate and immediate measures are taken. Overexploitation of the forests for wood products has resulted in the reduction of some of the economically important tree species like *C. molle*, *O. europaea* subsp. *cuspidata*, *Juniperus procera, C. africana*, *S. guineense*, *R. glutinosa*, *A. dimidiata*, *A. abyssinica* and *A. lahai*. The major factors for the destruction of the forests as ranked by the key informants were (in descending rank): (1) livestock grazing; (2) tree cutting for construction material and other purposes; (3) farmland expansion; (4) fire incidence; (5) introduction of exotic species; (6) soil erosion; and (7) road construction. Farmland expansion to the forests has been a less threat than livestock grazing and tree cutting since they are the protected areas, and Tara Gedam forest has been demarcated.

Role of the monastery in conserving the forest

The monastery plays a great role in the maintenance of the sacred forest since a long time. It is involved in protection of the sacred forest, tree planting in the monastery yard and giving advice to the local people on the importance of conserving the forests. The pressure of the local people on the forests, especially the sacred forest, is very low because of their strong religious belief and high respect to the monastery. Thus, the monastery is the most important institution in the conservation of the forests among others. However, legal protection should be strengthened due to the ever-increasing human pressure. Wassie et al. (2005) noted that protection of sacred forests in South Gondar is achieved through creating religious commitment and respect among the followers and legal protection due to increased human pressure. Zegeye et al. (2006) noted that the maintenance of sacred groves in the islands of Lake Ziway is solely attributed to the strong religious belief and high respect of the islanders to the church. Churches and monasteries have played a great role in the conservation of sacred groves in particular and forest resources of the country in general (Wassie et al. 2005; Zegeye et al. 2006).

Conclusions and recommendations

Tara Gedam and Abebaye forests possess high species richness and diversity, including endemics plant species. The similarity in species composition among the forests was low, indicating that each forest has its own characteristic species. Tara Gedam forest has higher diversity and evenness of woody species than Abebaye forest, and this is attributed to altitudinal difference, habitat diversity and low human disturbance as it is respected monastery. The diversity and evenness indices indicate the need to conserve the forests from both floristic diversity and human disturbance point of view.

The IVI values reveal the most ecologically important woody species in the forests and those to be prioritized for conservation. The DBH class distributions show that some species are in poor regeneration status due to human disturbance, particularly livestock grazing and unfavourable environmental conditions like poorly developed soil. The species having low IVI values and poor regeneration status need to be prioritized for conservation. *In situ* and *ex situ* conservation methods have to be implemented for the conservation of the priority species.

The forests provide various products such as fuelwood, construction material, timber, farm implements, medicines, animal fodder, bee forage and edible fruits. Despite their socio-economic and ecological importance, at present, the forests are under increased human pressure. Livestock grazing, tree cutting for various purposes and farmland expansion are the major threats to the forest resources. The monastery has played a vital role in the maintenance of the sacred forest since a long time. Since the local people have high respect and trust for the monastery, integrating conservation measures with the monastery would be more effective.

Therefore, in order to ensure the conservation, management and sustainable utilization of the forest resources, the following recommendations are suggested.

1. *In situ* and *ex situ* conservation methods have to be employed for the conservation of species having low IVI values and poor regeneration status.
2. There is a need to minimize livestock grazing, tree cutting and other human disturbances in order to allow the natural regeneration of woody species in the forests.
3. There is a need to promote terracing in the forests to control soil erosion and thereby enhance forest development.
4. It is necessary to encourage planting of indigenous and suitable exotic tree species in the agroforestry systems in order to reduce the pressure on the natural forests.
5. It is advisable to demarcate the forest boundary through strip tree planting in buffer zones in order to create a sharp undisputable boundary.
6. There is a need to formulate proper legal framework for protection of the forests.
7. It is important to allow sustainable utilization of the forest resources so as to develop sense of ownership in the

local people and ensure the long-term maintenance of the forests.

8. There is a need to create awareness in the local people and the government about the importance of conserving the forests.
9. Efforts should be made to provide the local communities with energy-saving stoves and alternative sources of energy in order to reduce the dependency on the forests for fuelwood.
10. It is important to facilitate the involvement of different stakeholders with proper integration so as to make the conservation and management of the forests more effective.

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Appendix 1. List of plant species identified from Tara Gedam and Abebaye forests with corresponding family, habit and spatial distribution.

Scientific name	Family	Habit	Tara Gedam	Abebaye
Acacia abyssinica	Fabaceae	T	x	
Acacia decurrens	Fabaceae	T *		x
Acacia lahai	Fabaceae	T/S	x	x
Acacia mearnsii	Fabaceae	T *	x	
Acacia pilispina	Fabaceae	T/S	x	x
Acacia saligna	Fabaceae	T/S *		x
Acacia seyal	Fabaceae	T		x
Acanthus polystachius	Acanthaceae	S	x	x
Acokanthera schimperi	Apocynaceae	T/S	x	x
Albizia gummifera	Fabaceae	T	x	
Apodytes dimidiata	Icacinaceae	T	x	
Asparagus africanus	Asparagaceae	S	x	x
Barleria ventricosa	Acanthaceae	S	x	
Bersama abyssinica	Melianthaceae	T/S	x	x
Bridelia micrantha	Euphorbiaceae	T/S	x	x
Brucea antidysenterica	Simaroubaceae	T/S	x	x
Buddleja polystachya	Loganiaceae	T/S	x	
Calotropis procera	Asclepiadaceae	S	x	
Calpurnia aurea	Fabaceae	T/S	x	x
Capparis tomentosa	Capparidaceae	S	x	x
Carica papaya	Caricaceae	T *		x
Carissa spinarum	Apocynaceae	S	x	x
Casimiroa edulis	Rutaceae	T *		x
Casuarina cunninghamiana	Casuarinaceae	T *	x	
Catha edulis	Celastraceae	S *		x
Celtis africana	Ulmaceae	T	x	x
Cissus quadrangularis	Vitaceae	L	x	x
Citrus aurantifolia	Rutaceae	T *		x
Citrus reticulata	Rutaceae	T *		x
Citrus sinensis	Rutaceae	T *		x
Clausena anisata	Rutaceae	T/S	x	
Clematis hirsuta	Ranunculaceae	L	x	x
Clematis longicauda	Ranunculaceae	L	x	
Clerodendrum myricoides	Lamiaceae	S	x	x
Clutia abyssinica	Euphorbiaceae	S	x	
Clutia lanceolata	Euphorbiaceae	S	x	
Coffea arabica	Rubiaceae	T/S *		x
Combretum molle	Combretaceae	T	x	x
Commiphora habessinica	Burseraceae	T/S		x
Cordia africana	Boraginaceae	T	x	x
Croton macrostachyus	Euphorbiaceae	T/S	x	x
Cupressus lusitanica	Cupressaceae	T *	x	x
Dichrostachys cinerea	Fabaceae	T/S		x
Dodonaea angustifolia	Sapindaceae	S	x	x
Dombeya torrida	Sterculiaceae	T/S	x	x
Dovyalis abyssinica	Flacourtiaceae	T/S	x	x
Ehretia cymosa	Boraginaceae	T/S	x	
Ekebergia capensis	Meliaceae	T	x	
Embelia schimperi	Myrsinaceae	T/S	x	
Erythrina abyssinica	Fabaceae	T/S	x	x
Eucalyptus camaldulensis	Myrtaceae	T *	x	x
Eucalyptus globulus	Myrtaceae	T *	x	
Euclea racemosa subsp. *schimperi*	Ebenaceae	T/S	x	x
Euphorbia abyssinica	Euphorbiaceae	T	x	
Euphorbia tirucalli	Euphorbiaceae	T/S	x	x
Ficus sur	Moraceae	T	x	x
Ficus sycomorus	Moraceae	T	x	x
Ficus thonningii	Moraceae	T/S	x	
Ficus vasta	Moraceae	T	x	x
Flueggea virosa	Euphorbiaceae	T/S		x
Gardenia ternifolia	Rubiaceae	T/S		x
Gnidia glauca	Thymelaeaceae	S	x	
Grewia ferruginea	Tiliaceae	T/S	x	x
Gymnema sylvestre	Asclepiadaceae	L	x	

Continued Appendix 1

Scientific name	Family	Habit	Tara Gedam	Abebaye	Scientific name	Family	Habit	Tara Gedam	Abebaye
Hibiscus macranthus	Malvaceae	S	x	x	*Ricinus communis*	Euphorbiaceae	T		x
Hymenodictyon floribundum	Rubiaceae	T/S	x		*Ritchiea albersii*	Capparidaceae	T/S	x	
Hypericum quartinianum	Clusiaceae	T/S	x	x	*Rosa abyssinica*	Rosaceae	T/S	x	
Indigofera tinctoria	Fabaceae	S		x	*Rubus steudneri*	Rosaceae	S	x	
Mimusops kummel	Sapotaceae	T	x		*Rumex nervosus*	Polygonaceae	S	x	
Moringa stenopetala	Moringaceae	T *		x	*Sapium ellipticum*	Euphorbiaceae	T/S	x	x
Myrsine africana	Myrsinaceae	T/S	x		*Schefflera abyssinica*	Araliaceae	T	x	
Nuxia congesta	Loganiaceae	T/S	x	x	*Schinus molle*	Anacardiaceae	T *	x	
Ocimum urticifolium	Lamiaceae	S	x	x	*Schrebera alata*	Oleaceae	T/S	x	x
Olea europaea subsp. *cuspidata*	Oleaceae	T/S	x		*Scolopia theifolia*	Flacourtiaceae	T	x	
Opuntia ficus-indica	Cactaceae	T/S		x	*Senna didymobotrya*	Fabaceae	S	x	x
Osyris quadripartita	Santalaceae	T/S	x	x	*Senna singueana*	Fabaceae	T/S		x
Otostegia integrifolia	Lamiaceae	S	x		*Sesbania sesban*	Fabaceae	T/S *		x
Otostegia tomentosa	Lamiaceae	S	x	x	*Sida ovata*	Malvaceae	S	x	x
Pavetta abyssinica	Rubiaceae	T/S	x	x	*Solanum anguivi*	Solanaceae	S	x	
Pavonia urens	Malvaceae	S	x		*Solanum giganteum*	Solanaceae	T/S	x	
Persea americana	Lauraceae	T *		x	*Solanum incanum*	Solanaceae	S	x	
Phoenix reclinata	Arecaceae	T	x		*Solanum marginatum*	Solanaceae	S	x	
Phytolacca dodecandra	Phytolaccaceae	L	x	x	*Spathodea campanulata* subsp. *nilotica*	Bignoniaceae	T *		x
Pluchea dioscoridis	Asteraceae	S		x	*Steganotaenia araliacea*	Apiaceae	T	x	x
Premna schimperi	Verbenaceae	T/S	x	x	*Stereospermum kunthianum*	Bignoniaceae	T/S	x	x
Protea gaguedi	Proteaceae	T/S	x		*Syzygium guineense*	Myrtaceae	T/S	x	x
Prunus africana	Rosaceae	T	x		*Teclea nobilis*	Rutaceae	T/S	x	
Prunus persica	Rosaceae	T *		x	*Terminalia brownii*	Combretaceae	T *		x
Psidium guajava	Myrtaceae	T *		x	*Triumfetta pilosa*	Tiliaceae	S		x
Pterolobium stellatum	Fabaceae	S	x	x	*Urera hypselodendron*	Urticaceae	L	x	
Pavetta oliveriana	Rubiaceae	L	x		*Vernonia amygdalina*	Asteraceae	T/S	x	
Rhamnus prinoides	Rhamnaceae	T/S *	x		*Vernonia brachycalyx*	Asteraceae	S	x	
Rhamnus staddo	Rhamnaceae	T/S	x		*Vernonia congolensis*	Asteraceae	S	x	
Rhoicissus tridentata	Vitaceae	L		x	*Vernonia myriantha*	Asteraceae	T/S	x	x
Rhus glutinosa	Anacardiaceae	T/S	x	x	*Ximenia americana*	Olacaceae	T/S	x	x
Rhus vulgaris	Anacardiaceae	T/S	x	x					

Presence of the species is indicated by x mark, T = Tree, T/S = Tree/Shrub, S = Shrub, L = Liana; * Cultivated plants.